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ABSTRACT

The performance of military systems (platforms, sensors and weapons) for real world operations is affected by both natural environment conditions and human performance. As shown in an earlier presentation (MORSS 71) human performance (decision making) is linked directly to the scenario environment conditions, present and past. As the Navy moves to increased automation on board ships, the software developed must incorporate the interaction of human performance (decision making) and the scenario environment conditions. The Systems Engineering Concept Model (SECM) is being used in several Navy programs to capture and analyze all relevant entities, their attributes and their interactions in a defined military scenario, first from the real world view and then from the software perspective. The process can be used to capture the functional requirements that insure the relevant interactions between the decision making and the scenario environment conditions are identified.

INTRODUCTION

United States Navy ships are facing an increasing variety of threats, such as high-speed, low-flying anti-ship cruise missiles (ASCM) that are beginning to appear in the inventories of many hostile forces. The Navy Ship Self Defense Program is focused on developing the ability of a single ship to defend itself against an attack involving a single threat or a stream of such threats. To support the Ship Self Defense program, the Navy is fielding a suite of highly automated and integrated military systems to aircraft carriers and the Whidbey Island, Wasp, and San Antonio classes of amphibious assault ships. During the development of these ships, it is not practical to test their integrated self defense capabilities against live threats, so the Navy is increasingly using Modeling and Simulation (M&S) to supplement live exercises to test and evaluate Ship Self Defense. (Reading and Pobat 2000.)

In the operational world, the natural environment plays a significant role in determining the performance of the threat and ship defensive systems and how the warfighters utilize them. The effect that environmental factors have on the performance of the individual military systems is well understood from land and sea-based tests. For sensors such as radars, these environmental factors include refraction, attenuation, and clutter. (Skolnick 1990.) Ship Self Defense, however, involves the performance of the complete ship system (the ship itself, the integrated military systems, and the warfighters) when engaged in a self-defense combat situation. The role that environmental factors play in Ship Self Defense is not as well understood and is complicated because the action of complete ship system during a combat situation can alter the environmental factors involved.

M&S offers the option of exploring how a wide range of environmental conditions can affect ship system performance in a self-defense combat situation and vice-versa provided that the simulation used appropriately represents the operational world. In order to achieve this goal, the simulation must include appropriate models as well as their attributes, behaviors, and interactions for the various military systems, the ship itself, the warfighters, and threats.

Many studies have been conducted on representing the impact of environmental effects on military systems in M&S applications (e.g., Chadbourne et al. 1998 and Douglas et al. 2001). However, there has been only limited research into the role that environmental factors play in the human decision making processes related to the use of military systems. One cognitive model involving terrain is described in Juarez-Espinosa and Gonzalez (2004).[1] In this paper, we address the general issues of what role the environment can play in human decision making process. We then address the issues from a military operations standpoint to address how the environment needs to be represented in the M&S tools being used to develop and test the performance for Ship Self Defense.

In this paper, we describe our approach and assumptions made on how one can incorporate human performance into simulations of the Ship Self Defense concept. Next, we present a "real world view" of the decision making processes involved in ship self defense. Then, we present a conceptual representation of the human decision making process from both a general perspective and how it is represented in the military domain. Next, we discuss how these processes can be incorporated in an existing simulation system that has been developed to support the Ship Self Defense program. Finally, we present a summary of these efforts and where we are proposing to go in future work.

APPROACH AND STATEMENT OF ASSUMPTIONS

The Navy has mandated that that specific ship classes must have self defense capability against a raid of incoming ASCM threats and that this capability will be assessed using the Probability of Raid Annihilation (PRA) as the primary Measure of Effectiveness (MOE).[2] The PRA Assessment Process Standards and Architecture (PS&A) has been developed to provide an approved roadmap for each ship class's managerial and technical teams to use in assessing the PRA MOE for that ship class. As part of the risk mitigation strategy, the PS&A is designed to meet Operations/Operational Evaluation (OPEVAL) requirements in a consistent and adequate manner and to reduce costs by using standard practices and tools as well as by building on previous ship class work.[3] For more details on the PRA Assessment PS&A see Blake et al (2003).

The PRA MOE is difficult to assess by the traditional sea-based and land-based testing. Cost is always a limiting factor but a more important consideration is the requirement to test the complete ship system along a timeline, not just the individual components of the ship. That is, the PRA MOE must be assessed using complete scenarios with all relevant military components, ship and threat, behaving and interacting along a timeline as they would during actual ship self defense situations. Furthermore, the scenarios must include a reasonable range of environmental conditions that would be appropriate during such ship self defense situations. For these and other reasons, the PRA Assessment Process includes interoperable simulations, for example, the PRA Assessment Simulation Testbed. The sea-based and land-based testing trials are incorporated as part of the robust validation process. For more information on the ship self defense PRA, see Grigsby and Blake (2001) and Reading and Sawyer (2003).

To date the interoperable simulations included in the PS&A have not included any representations of the warfighters. While the new ship self defense systems are highly automated, some components still require an EW operator, for example, the SLQ-32A during combat situations. The key human performance factor provided by the EW operator is decision-making. The addition of a human performance (decision-making) model in the Ship Self Defense simulations requires that the environmental representation be provided for that model as well as for the other ship and threat system representations. The approach used in this paper to establish the human performance (decision-making) and natural environment consistency across Ship Self Defense interoperable simulations will be an extension of that developed for the PS&A to handle military systems and natural environment.

The PS&A is based on common systems engineering techniques and tools. The first steps include defining the problem objectives and scope and then establishing the requirements and conceptual views appropriate to that problem.[4] The conceptual views, in particular, are critical in defining the relationships among the military systems, warfighters, and the natural environment. The Systems Engineering Concept Model (SECM) methodology is being used in several Navy programs in addition to Ship Self Defense to capture and analyze all relevant entities, their attributes and their interactions in a defined military scenario, first from the operational or real world view and then from the simulation perspective.

REAL WORLD VIEW

The suite of military systems involved in Ship Self Defense includes sensors; weapons to destroy the threat (a "hard" kill) and weapons to decoy a threat (a "soft kill"); and the accompanying processing and control software and hardware (consoles, displays and computers). Hard-kill weapons can include a variety of missiles. Soft-kill weapons are decoys denoted as seduction or distraction. The particular components vary from ship to ship.

Figure 1 shows a ship in a combat situation under attack from an ASCM threat. The role of the natural environment for Ship Self Defense is highlighted by this diagram. An ASCM operates in and has its system performance affected by the natural environment. The natural environment also impacts the performance of the ship and the ship's sensing and defensive systems. First, the natural environment modifies the radio frequency (RF) signals that pass through it. Second, the ship and the EW System will pitch and roll in response to wind and waves, thereby affecting the performance of the Ship Self Defense. The interactions between the threat and the ship occur exclusively through the natural environment until one of three things occur: 1) the threat damages the ship, 2) the ship's weapons kill the threat (via a hard or soft kill), or 3) the threat misses entirely. All of the actions noted above occur as responses to the threat misses entirely. All of the actions noted above occur as responses to the state of the common natural environment.

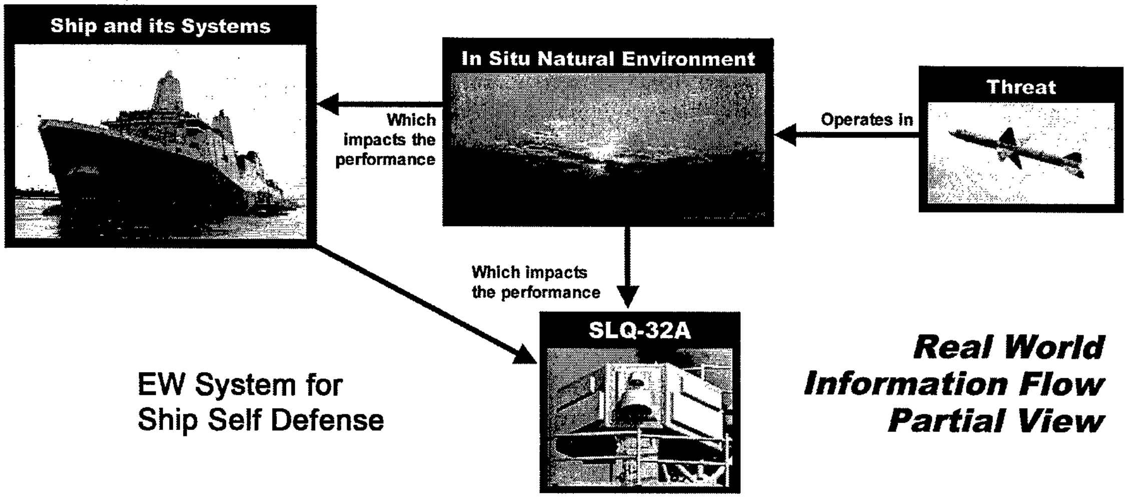

Figure 1. A generalized representation of the relationships between the environment and threat and ship defensive systems performances.

The conceptual view shown in Figure 1 is expanded when system operators are included as shown in Figure 2. The system operators receive and respond to information provided by the ship's systems, including weapons and sensors. The impact that the external natural environment has on this information depends on the particular ship's system providing the information. Note however, that the performance of the system operators included in Figure 2 are not affected directly by the external (i.e., outside the ship) natural environment, but their performance and actions are impacted by their perceptions of the natural environment as presented to them by their sensors and other ship information systems. In addition, the system operators must perform their jobs in a microclimate of environmental conditions inside the ship that might have a detrimental impact on their physical and behavioral performance (i.e., decision making). Capturing the details of how the natural environment affects the systems operators requires an understanding of how human performance (decision making) functions in general.

CONCEPTUAL REPRESENTATION OF THE DECISION MAKING PROCESS

In Chapter 8 of their book, Wickens and Hollands (2000) have described the decision making process in detail, including a diagram that shows the operations and flow involved. Blake and Meyer (2003) adapted this diagram, which is shown in Figure 3, to demonstrate where the natural environmental processes and data can appear in the decision-making process. In Figure 3, the components that involve the natural environment are shown as green ovals. The orange boxes show the decision making processes. Note that Options Risks may also be part of the Long Term Memory. Different models and theories exist for each stage shown – sensory processing, perception, long term memory, and cognition – and for the interactions among the stages.

This figure merely suggests the stages involved in decision making in dynamic scenarios. The decision making process outlined in Figure 3 will be discussed in more detail later, but briefly the decision maker receives cues through the five senses, analyses those cues together with available memories, selects a response, and then executes that response. The results of the response executed become part of recent past and the process is repeated.

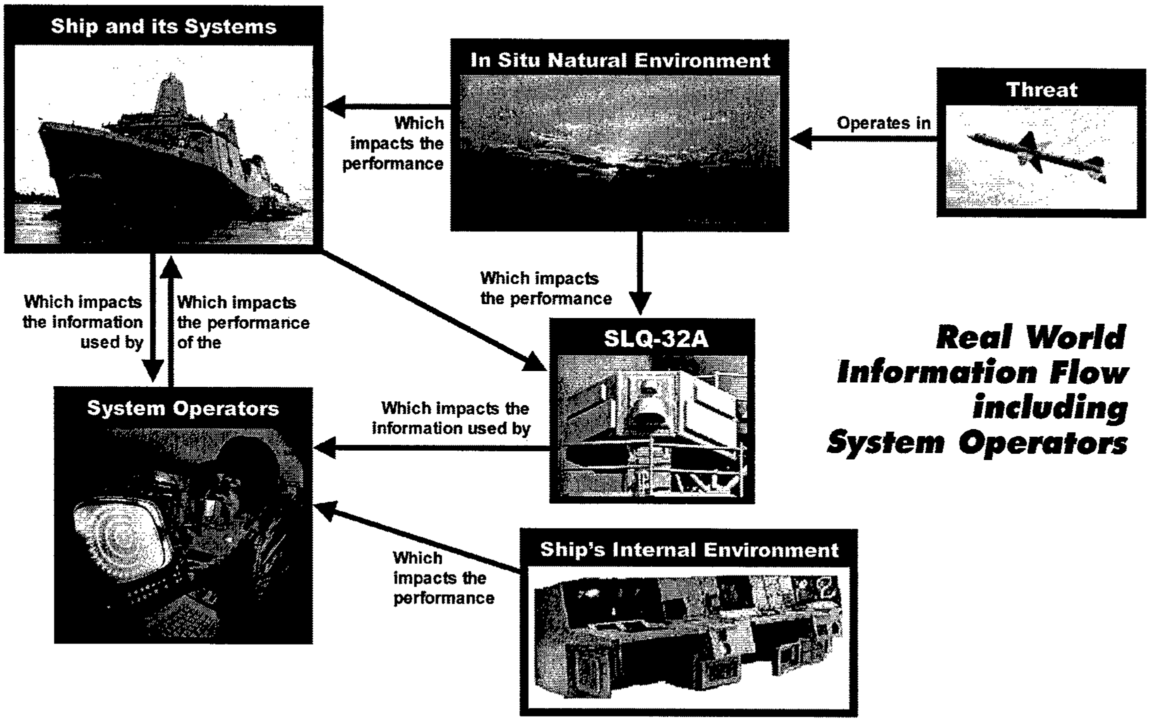

Figure 2. A generalized representation of the relationships between the environment, threat and ship defensive systems performances, and human decision makers.

The decision-making process shown in Figure 3 may be understood by comparing to the United States Marine Corp statement of Observe, Orient, Decide, and Act (OODA). The left hand column is Observe, the second column from the left is Orient, the second from the right is Decide and the right hand column is Act. For the Marine on the ground, the Cues (the light green oval in Figure 3) are provided directly by the in-situ environment. For the System Operators in Figure 2, the Cues are provided by the displays (visual and auditory) from information obtained by the ship systems and affected by the in-situ environment.

MILITARY DECISION MAKING

The decision making process shown in Figure 3 is general for human performance in any situation when environmental processes are relevant. The decision making process for a single System Operator is only one part of the overall Ship Self Defense process during a combat situation. A representation of the overall Ship Self Defense processes in which the roles of human operators, automated response systems, and natural environmental processes is shown in Figure 4. The Blue symbols on the left signify the data generated and used by the ship systems and operators, while the Red symbols on the right represent those of the Threat (no operators). The decision making processes are shown in the lower left hand loop starting just with Blue's Perception of the Environment.

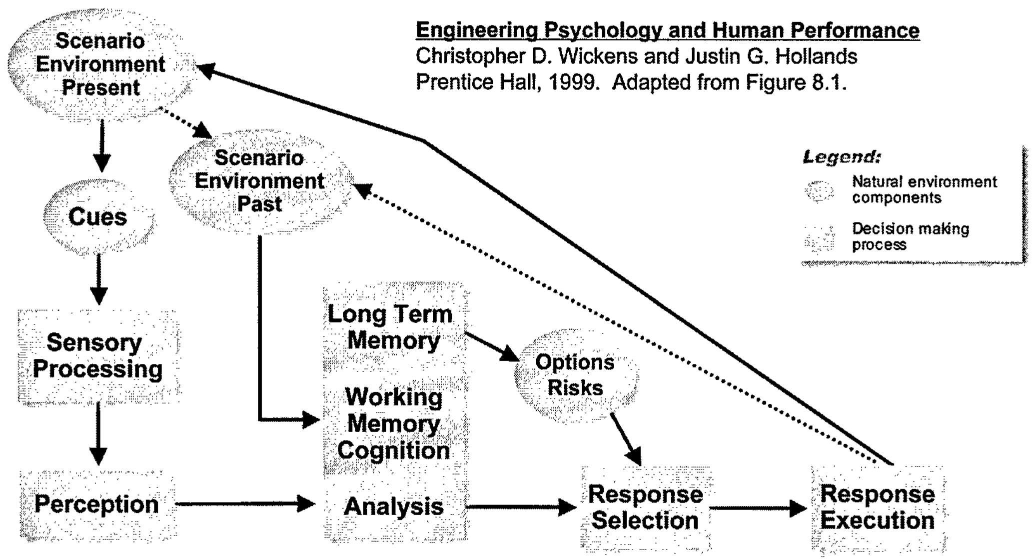

Figure 3. A schematic representation of the human decision making process in which environmental factors are considered.

At the start of the engagement, both the blue systems and the threat systems are impacted by the state of the environment as noted by the symbol "common physics environment" (natural environment in Figures 1 and 2). The physical state of the environment directly affects the threat aerodynamically and indirectly via the perceived environment as viewed by its sensors. The Threat's responses to its perceived environment are driven by preprogrammed tactics that are embedded in the threat's process and control systems. The blue systems are impacted in a similar fashion. The blue sensors detect a threat signature and generate the blue sensed threat environment (cues in Figure 3) which can be responded to by either human driven or automatic defense responses.

Blue sensors not only provide information about the threat but also about the *in situ* natural environment as determined by the onboard weather sensors. All of the observations of the threat and the natural environment form part of the perceived environment that is the basis of the information set used in decision making. For combat situations in general, red and blue forces operate in a common natural environment, but the two forces may receive different information, observations and forecasts, about the natural environment and, hence, have different perceptions of the natural environments they operate in. These differences in their perceived environments play a critical role in determining the progress and advantages in combat situations.[5]

Blue's memory of past engagements, intel on threat capabilities and ship tactics, doctrine, and rules of engagement are either in the human memory or stored in readily accessible databases and are considered along with the perception of the environment in an the analysis of the threat environment. This analysis includes a determination of what the operational situation is and what the risks and options are for employing the Ship Self Defense systems. If the weapons deployed eliminate the threat, then the engagement is over. If not, or if additional threats appear, then the systems are reengaged.

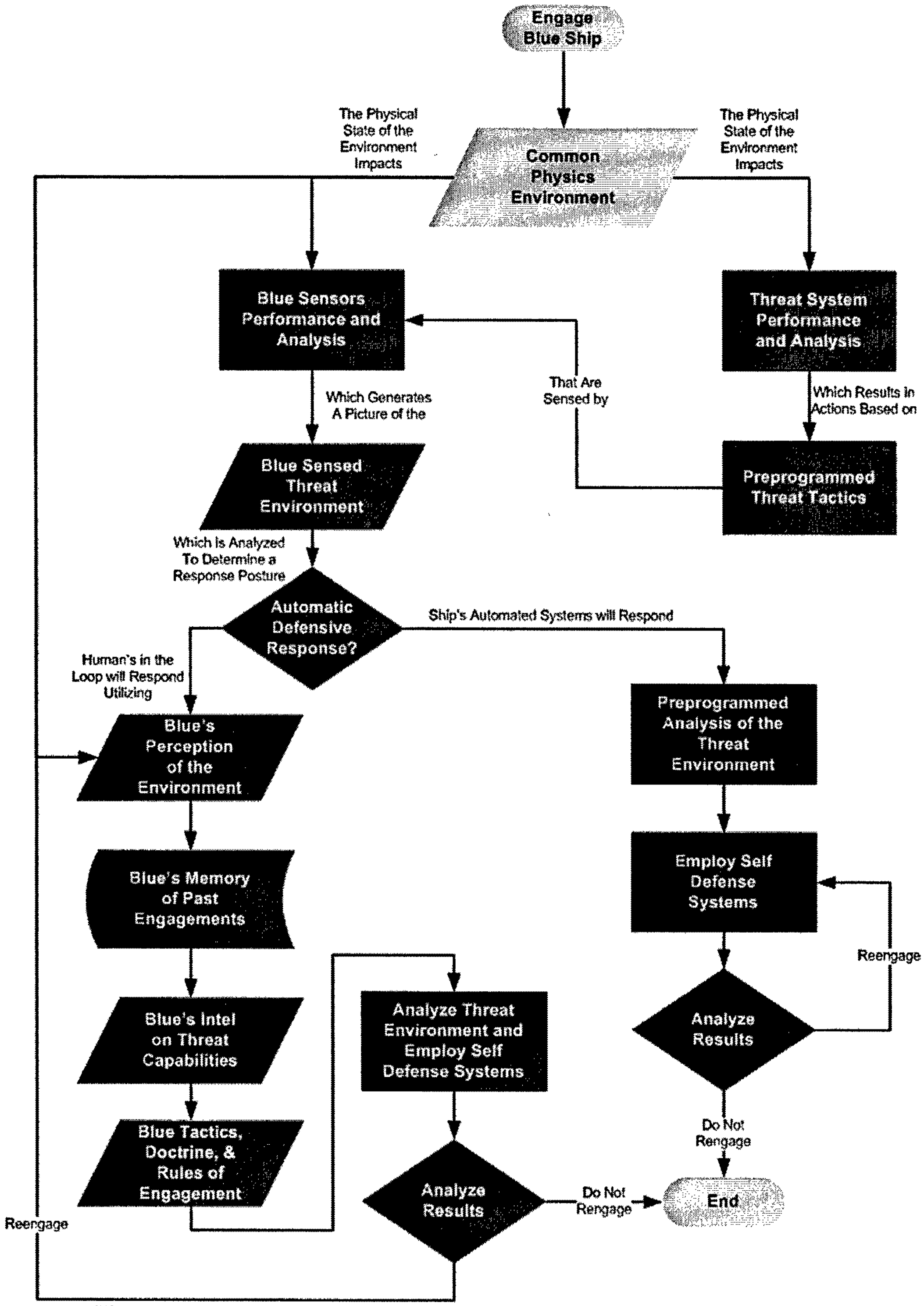

Figure 4. A representation of the data flows and decision making processes in a ship self defense process during a combat situation.

As stated earlier, Ship Self Defense is highly automated so most military systems can operate either with System Operators or in a fully automated mode. These military systems are represented in the fully automated mode in the interoperable simulations used for the PRA Assessment of the MOE. The exception at this time is the SLQ-32A electronic warfare (EW) system which has an EW operator in the decision making loop but does not have a fully automated mode.

As the military increasingly uses M&S for training, analysis and acquisition, the demand has grown for more robust models both of military systems and of the role warfighters play in using them. In recognition of this growing demand, the Defense Modeling and Simulation Office (DMSO) requested that the National Academy of Sciences undertake a comprehensive review of the human behavior representation (HBR) for military simulations. The resulting report (Pew and Mavor 1998) describes a wide range of HBR models both for individual warfighters and organized units of varying size. These HBR models cover various aspects of human performance including human decision making, situation awareness, planning and command and control. HBR models range in complexity from time delay models to adaptive learning models. Variability in human response times due to stress, workload and other factors may be incorporated by randomly varying either the response times or the course of action selected. In the following section, we will discuss how the results of this study can be incorporated in an existing simulation system developed to support the development of Ship Self Defense systems.

PRA ASSESSMENT SIMULATION TESTBED

In the PRA Assessment PS&A, the Ship Self Defense systems are analyzed to identify the functional capabilities that impact the PRA MOE which are then captured in appropriate models of the various systems. These models, in turn, are clustered into several interactive simulations, which are linked over a High Level Architecture (HLA) Run Time Infrastructure (RTI), to form a federation called the PRA Assessment Simulation Testbed. Each ship class will have a different testbed, corresponding to the different suite of military systems included. A general version of the Ship Self Defense Testbed, shown in Figure 5, models threats, a variety of LPD17 sensors, ship tactics, and the natural environment. The display is notional and does not represent any specific testbed.

The ship sensor systems displayed include two RF active radars, the SPQ-9B and the SPS-48E, and the EW System, SLQ-32A. The two Processing and Control systems, CEP and SSDS, are in the Sensor Fusion and Control System Federates, respectively, shown in the lower left corner. The Threat/EA Federate in the upper left corner of the figure is the most complex and includes a threat model, a decoy model and the relevant ship functionalities. The decoy model in the federate is that of a Nulka. Only the key ship functionalities are included, the ship's RF signature (radar cross section) and the ship motion. The ship motion, primarily orientation and pitch, affect the performances of the ship self defense combat systems as well as the performance of the approaching threat. The ship's hard kill weapon is the Rolling Airframe Missile (RAM).

The common physics environment data is provided by the Scenario & Environment Federate. This federate also provides the scenario data such as: initial ship position, date, time of day, playbox, etc. The common physics data provided corresponds to the natural environment in Figures 1 and 2 and the common physics environment in Figure 4. This natural environment data must be physically and dynamically consistent to form a Verified and Validated Natural Environment Representation (Hummel and Blake 2001). For example, the wind direction and speed must be consistent with the wave height and direction. Further, this common physics environment data is provided to each federate to ensure that each federate is on "a level playing field." The perceived environment, described in the last section, is that obtained by the various sensors, ship and threat. The models for these sensors are contained within the various federates and, therefore, the perceived environment, is developed within these federates at runtime.[6]

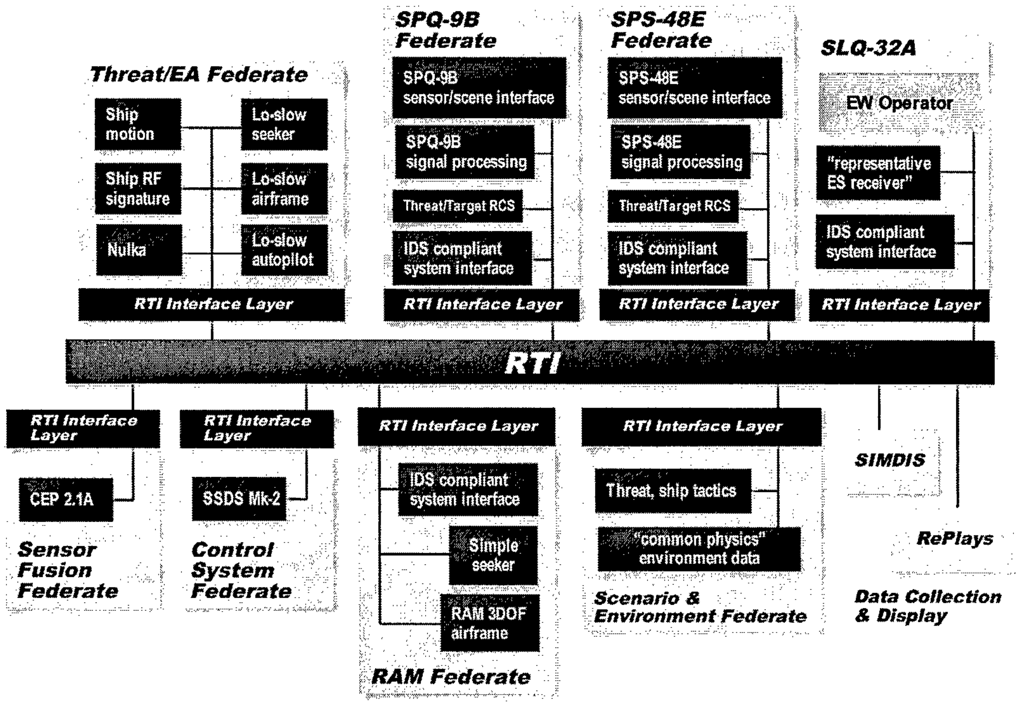

Figure 5. The Modeling and Simulation Components that make up the Ship Self Defense PRA Assessment Simulation Testbed.

Many of the models contained in the various federates shown in Figure 5 are legacy models or are rehosted software for the operational military systems. Whenever appropriate, the models represent the operational (actual) military systems, running in the fully automated mode. The exception is the SLQ-32A, which must have an EW Operator for combat situations.[7] Thus, the Testbed must contain an EW Operator model that has the appropriate functional capabilities. As this EW Operator is developed, its requirements for the environment data must be identified so that data can be provided by the Scenario & Environment Federate. At this stage of development, the SLQ-32A federate is planned as a combination of software models to represent the functionalities in the SLQ-32A, together with the Electronic Support Enhancement Processing Unit as Hardware-in-the-Loop. The EW Operator will be included as one of the model components in the SLQ-32A federate.

In Chapter 12 of the report by Pew and Mavor (1998), they recommend a methodology for developing human behavior models and identify the need to understand what tasks are being performed as the critical first step in selecting or constructing the appropriate HBR model. When restated in M&S terminology, the critical first step is to identify the simulation requirements for the HBR model.[8]

The requirements for the Ship Self Defense PRA Assessment Simulation Testbed are lengthy and specific to each ship class. However, the minimum EW Operator model requirements can be generalized as follows:

1. The EW Operator model must select the course of action from the cues provided by the Testbed during runtime.
2. The EW Operator model must execute the course of action.
3. The EW Operator model actions must occur at the appropriate time during the runtime of the Testbed.
4. The EW Operator model actions must take the appropriate amount of time to execute during the runtime of the Testbed.

Based on these requirements, the EW Operator model should receive the perceived environment as input and will provide the appropriate course of action, including timing, as output. The emphasis of these requirements appears to be on response selection and execution. In actual combat situations, the EW Operator executes the course of action through a series of keystrokes. Therefore, an appropriate EW Operator model might appear to be one that selects the course of action depending on the input and transmits that course of action after a time delay that corresponds to the time it takes an EW Operator to execute the appropriate series of keystrokes. As shown in Figure 6, this type of EW Operator model only captures the time delay associated with the last step in the decision making process, not with the preceding steps. Can the time delays associated with the preceding steps be identified and captured in a simple EW Operator model?

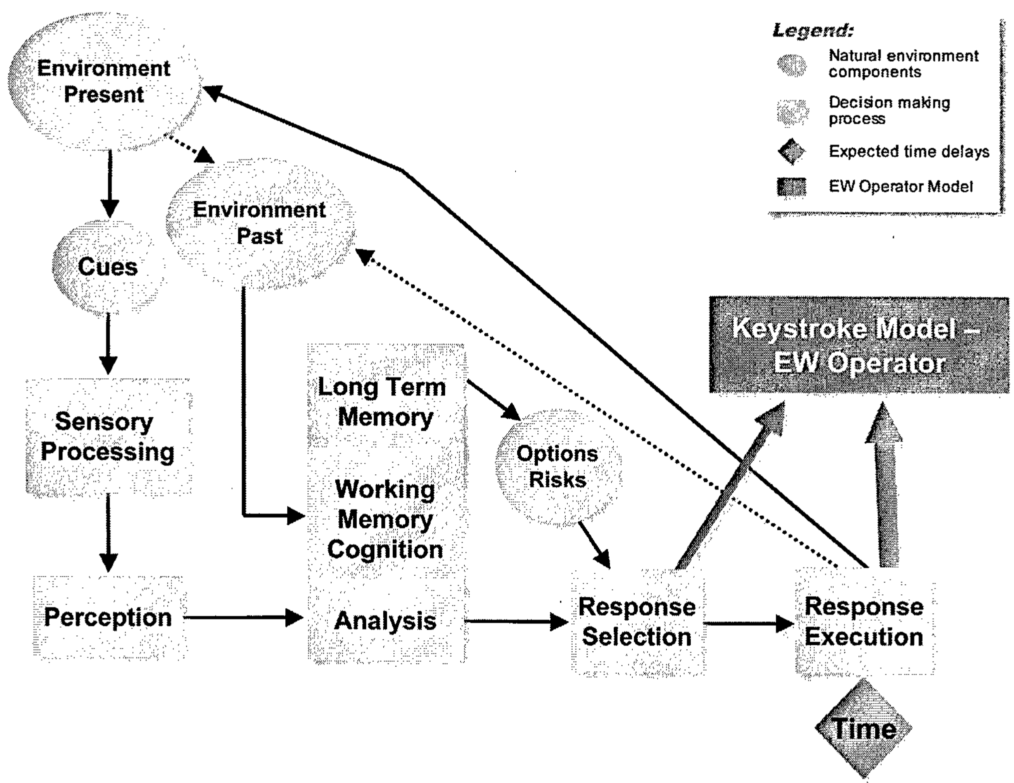

Figure 6. EW Operator model as part of human performance (decision making).

In order to identify the time delays associated with each step in the decision making process as well as the link to perceived environment, each step in Figure 6 must be examined in more detail, starting with sensory processing as shown in Figure 7. The cues are external to the EW Operator and include screen and casualty radar screens, although the combat situation is more complex. Both informative and extraneous cues are received. However, only some of the cues are passed on to the perception stage. Both selective attention and clue filtering are used to determine which cues are perceived. For example, an operator who is focused on a visual cue (selective attention) may not be aware of (receive or internalize) an auditory cue that is present. Or an operator who is focused on visual cues may be aware of only a change in the pattern, not the background pattern itself (clue filtering). Although not detailed in Figure 7, clue filtering is affected by expectations of what the cues will be. These expectations are based, in part, on the scenario environment, present and past. Remember that for the EW Operator, the environment refers to the perceived environment, not the natural or common physics environment shown if Figures 3 and 4. Knowledge from previous experience (learning) and automatic constraints on attention affect selective attention and clue filtering.

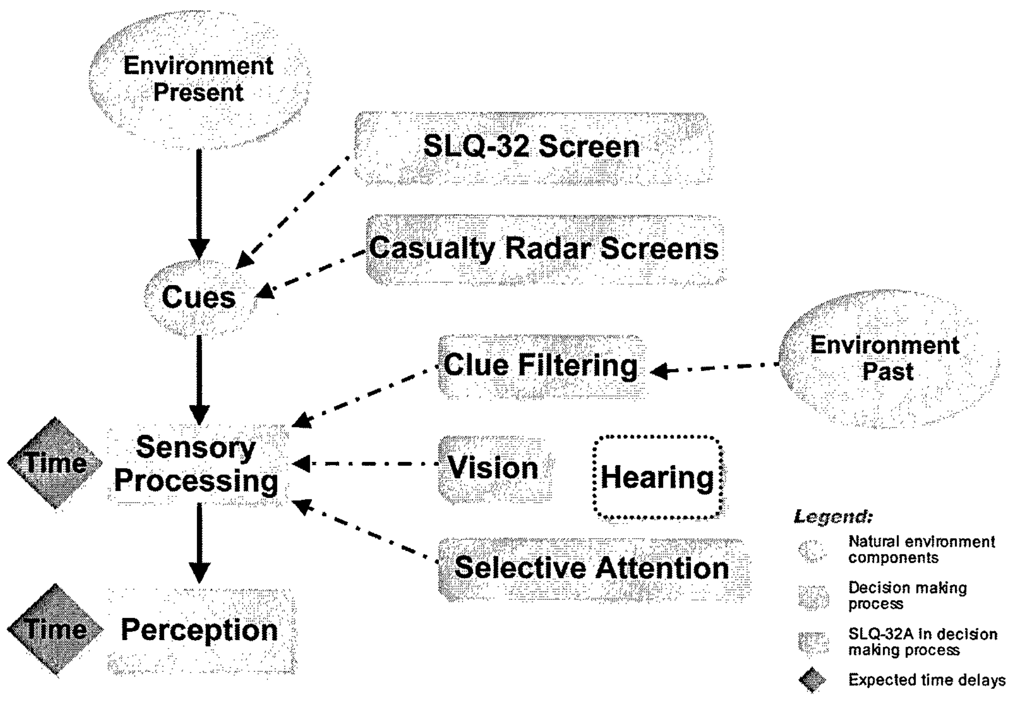

Figure 7. Representation of the processes in decision making by EW Operator – the sensory processing step.

Once the cues have been selected and sent to the brain, they must be interpreted for meaning. For example, the visual cues from the SLQ-32A screen must be interpreted as to whether or not an emitter is present while those from the causality radar screens are interpreted as to whether or not there is a hard track present. The processes that make up this step are represented in Figure 8. However, the hard track is not merely a matter of yes or no but actually has levels certainty ranging from 0 – 7 depending on the situation. An increasing number of options for interpretation generally means an increasing time for the perception stage.

The Analysis stage is the one most commonly associated with decision-making. The environment past is part of the information, along with that perceived environment present provided by the cues, that is analyzed to determine what the combat situation is. The blue box to the right shows four possible states, even without including the rankings of 0 – 7 for whether there is a hard track. Thus, the analysis is not automatic but requires a weighting of the information available. Analysis will take time, and the amount of time will vary with the perceived combat situation.

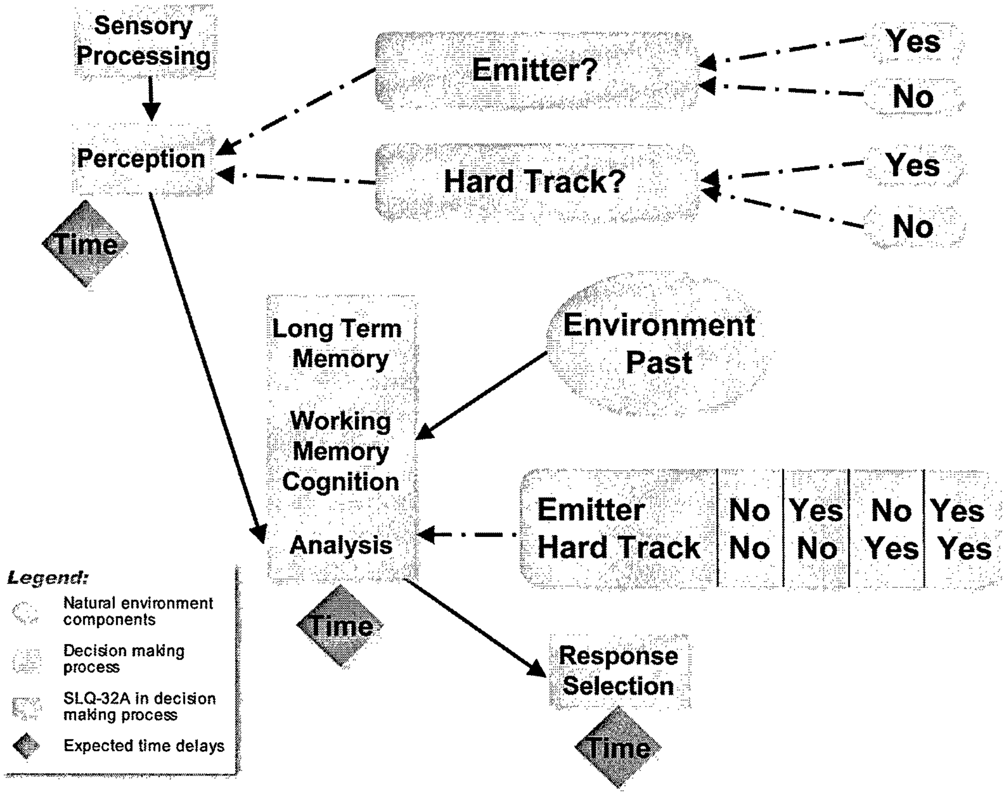

Figure 8. The processes involved in decision making by an EW Operator – the perception and analysis steps.

The remaining step in decision making that remains to be examined is that for response selection as shown in Figure 9. Here, the risks and options in Figure 3 have been separated for detailed discussion. Remember that the risks and options are stored in the long term memory. The options are for no launch of weapons or to launch one or more weapons in various combinations. Note that the EW Operator does not directly control the launching of all weapons shown. There are risks for launching or not launching weapons when a target is detected. The examples shown denote well documented combat situations. The *USS Stark* did not fire on an approaching target, a response selection that resulted in military lives lost. The *USS Vincennes* did fire on a target that turned out to be a civilian transport, not a threat, with tragic consequences. Again, the availability of several options along with the knowledge or the risks involved for any option will increase the time needed for this step.

The response execution will modify the environment present, both the common physics environment and the perceived environment. The modifications to the environment present can be determined by analyzing the results of the actions taken.

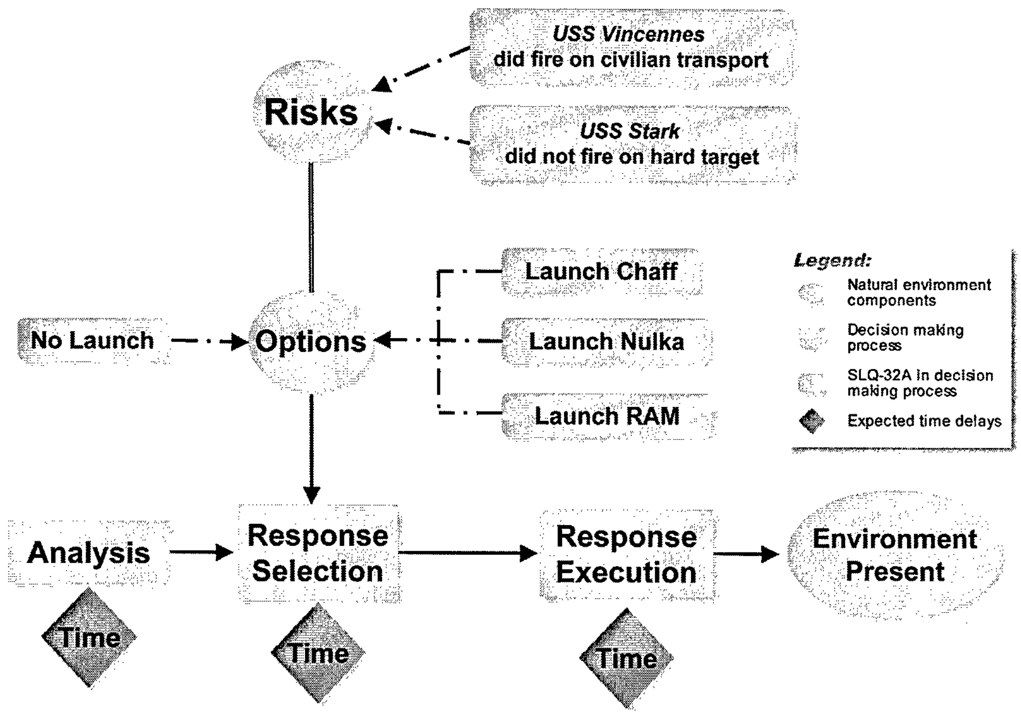

Figure 9. The processes in decision making by an EW Operator – the response selection and execution steps.

FUTURE EFFORTS TO INCORPORATE HBR INTO THE PRA TESTBED

In the previous discussions we have presented the methods by which human behavior **can** impact the decision making process in ship self defense systems. Now, we want to address the issues associated with how to implement these processes in an actual simulation environment, in this case the PRA Testbed.

The detailed analysis delineated in Figures 7 – 9 indicate where additional time delays can (and will) occur in the decision making process of an EW Operator. Further, the links between the environment, present and past, have been highlighted. The next step is to obtain actual data for the time delays that occur at each step what other factors are occurring at those steps because they may influence why the delays occurred. This can be done with observations combined with analytic studies (Pew and Mavor, 1998, p. 325). Two main sources are potential opportunities for observing the EW Operator in action: live exercises and simulators.

Live exercises frequently focus on the performance of the individual military systems such as the SLQ-32A, not on the system operators or the environmental conditions. In fact, system operators are not always involved in the live testing. However, the LPD17 PRA Assessment teams are working with the teams involved in the live testing to ensure that the additional information is recorded.[9] These observations of EW Operators during live testing, if available, must be structured to capture as much external data (the natural environment and the visual cues) and internal data (what the operators are thinking and doing as they view the screens. Even under optimum observing conditions, the range of scenarios, including the natural environment, will be limited. Further, the operators will be performing under test conditions, not combat conditions.

Simulators have been used in other applications to observe human performance in order to develop cognitive models. For example, Remington et al. (2004) describe observations of air traffic controllers being trained on simulators as they handle complex multi-tasking situations. Simulators provide a wide range of scenarios and environmental conditions without the possibility of serious consequences found in actual airport operations. However, the knowledge that there will be no serious consequences removes the element of stress that affects the performance of air traffic controllers.[10] Wickens and Hollands (2000, Chap. 12) discuss in detail the links between stress and human error, starting with the effect that stress has on sensory processing. With this limitation in mind, the simulators still offer one of the few sources for observing human operators making decisions under a wide range of conditions.

Simulators are used to train EW Operators for a wide range of scenario environment condtions.[11] The observations of the EW Operators being trained must capture the link between their performance and what they see on their screens. Observational data of EW operators using simulators can be obtained by human observers or captured through software applications (Fernlund and Gonzalez 2004).

Regardless of the source of observations of EW operators, live testing or simulators, all three aspects of the operations must be captured: the human performance, the perceived environment (the cues or screen displays) and the scenario natural environment. The observations will not be comprehensive as it is not possible to determine exactly how much time is spent on each step in the decision making process. However, if the observations are made carefully, the resulting analysis can provide a better determination of the time required for each step in the decision making process as well as the time to execute the keystrokes. It is expected that the time for the decision making process as well as the exact sequence of keystrokes will depend on the perceived environment and, in turn, on the natural environment. This information can be used to improve the EW operator keystroke model to more closely resemble what happens in operational situations and to provide consistency between human performance (decision making) and the natural environment across integrated naval simulations, specifically the PRA Assessment Testbed.

The EW operator time delay data, coupled with the environmental factors discussed previously, can be used with a tool called the Framework for Addressing Cooperative Extended Transactions (FACET) to model the complete end-to-end Ship Self Defense decision making process. FACET was developed at the Argonne National Laboratory as part of the Dynamic Information Architecture System simulation framework system (Hummel and Christiansen 2000). FACET was developed to describe the processes involved in course of action development and execution. Originally developed to support the modeling of a complete healthcare provider, FACET was used to capture the processes and data used by humans in all aspects in a healthcare system including the patients who are responding to physiological changes in their bodies and deciding if they need to see a doctor to the actual healthcare providers who must respond to symptoms described by the patients and the data that collect about the patient's state and develop a course of treatment. FACET was developed from a generalized perspective and can be used to model the social interactions between any animal life form. FACET can also be used to model the decision making processes of physics driven entities as well.

SUMMARY

The US Navy is increasingly using M&S to supplement live exercises and testing for training, analysis and acquisition. The performance of military systems in combat situations is affected by the performance of the warfighters; both in turn are affected by the natural environment. The interoperable simulations developed must reflect the functional relationships in a consistent manner among the military systems, warfighters and natural environment. Specifically, human performance (decision making) and the scenario environment are linked in the real world and therefore must be consistent across integrated naval simulations. In this paper we have presented the first steps in defining the requirements for human performance representation and natural environment representation that is consistent across integrated naval simulations.

The Ship Self Defense PRA Assessment PS&A includes the methodology, SECM, for establishing consistency between the military system models and the natural environment representation data. This methodology has been extended to demonstrate how consistency can be established for human performance (decision making) as well. At the conceptual level the steps followed are:

- Examine the relationships for Ship Self Defense in combat situations.
- Examine the general human performance (decision making) process with the effect of the environment included.
- Develop the military decision making process for Ship Self Defense in a combat situation.
- Analyze the PRA Assessment Testbed to determine the requirements for an EW operator model. Based on the requirements, a keystroke model will be used. Keystroke models generally capture only the response execution actions, not the complete decision making process, including the impact of the natural environment on that process.
- Analyze the decision making process specifically for a keystroke EW operator model to determine the links among the steps in decision making, the cues provided by the military system sensors, and the common physics environment.

The analysis indicates that the keystroke model for an EW operator should incorporate time delays and keystroke sequences that depend directly on the cues (perceived environment) that, in turn, depend on the natural environment representation provided. Even a simple time delay model of human performance can be linked to the scenario environment.

The next steps, reserved for future work will be to obtain the data needed to establish the values for the time delays and the keystroke sequences for various scenario environment conditions. Such data can be obtained from live testing and from simulators used to train EW operators. Observations of EW operators must be structured, if possible, to identify the mental processes in decision making as affected by the scenario environment presented.

ENDNOTES

[1] The authors welcome additional information about such studies.

[2] "AAW Capstone Requirements Document" Chief of Naval Operations, 5 February 1996.

[3] "Navy Ship Self Defense Combat Systems Engineering Probability of Raid Annihilation (PRA) Assessment Process Standards and Architecture (PS&A), Version 1.1, May 2003 may be obtained from VisiTech, Ltd, 535 E. Braddock Road, Alexandria VA, 22314, Email: blake@visitech.com.

[4] The Program Executive Office (PEO) Integrated Warfare Systems (IWS) Systems Engineering Process, which does address Modeling & Simulation, is the guide for the PRA Assessment PS&A.

[5] The difference between the "common physics environment" in which the military systems operate and the "perceived" environment which the systems operators use in decision making as well as the roles that both types of information can play in M&S has not received sufficient recognition. See Lucas et al (2000) for additional information.

[6] Many of the high fidelity physics models are run ahead of time and the results are stored in databases that are accessed at runtime.

[7] Information provided by Kevin Brown (US Naval Research Laboratory – DC), 2003, unpublished paper.

[8] The lead author thanks Dr. Ruth Willis (Advanced Information Technology Branch, US Naval Research Laboratory – DC), 2002, for discussions on human behavior representation models. Dr. Willis emphasized both the importance of and difficulties in establishing requirements for HBR models as a first step in developing appropriate HBR models.

[9] The lead author thanks Duane Coleman (Naval Surface Warfare Center – Corona Division) for this information.

[10] The authors thank Bruce E. Eckstein (FAA, Washington, DC) for discussions about using simulators in training air traffic controllers.

[11] One example is the EWPro™. http://www.rdsi.com. Last accessed on 11 November 2004.

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DESCRIPTORS

Human performance
Decision making
Natural environment
Perceived environment
Probability of Raid Annihilation (PRA)
Modeling and Simulation (M&S)
Ship Self Defense (SSD)

LIST OF ACRONYMS

AAW	Anti Air Warfare
ASCM	Anti Ship Cruise Missile
BRIMS	Behavior Representation in Modeling and Simulation
CEP	Cooperative Engagement Processor
EW	Electronic Warfare
FACET	Framework for Addressing Cooperative Extended Transactions
HBR	Human Behavior Response
HLA	High Level Architecture
LPD	Amphibious Transport Dock
M&S	Modeling and Simulation
MOE	Measures of Effectiveness
MORSS	Military Operations Research Society Symposium
OODA	Observe, Orient, Decide, and Act
OPEVAL	Operations/Operational Evaluation
PRA	Probability of Raid Annihilation
PS&A	Process Standards and Architecture
RAM	Rolling Airframe Missile
RF	Radio Frequency
RTI	Run Time Infrastructure
SECM	Systems Engineering Concept Model
SSD	Ship Self Defense
SSDS	Ship Self-Defense System